Ceremonies of Measurement *

Rethinking the World History of Science

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It's commonly imagined that practices of measurement can somehow escape the localised limitations of each culture and society. Quantification's ambitions, therefore, play a major role in world histories and, above all, in the enterprises of scientific and commercial networks. It's claimed that measures of commodities and of data much help mobility and mastery. The techniques and results of such measurement processes are, so it seems, understood in the same way everywhere, as if they had no need of translation or of mediation, as if they could speak for themselves. No doubt all this explains why some historians have identified the coming of European modernity with the rise of the quantitative spirit, and, simultaneously, with the capacity of these Europeans to travel, loot, accumulate and dominate outwith their own world and, in principle, everywhere.[1]

Localisation and displacement

The man who in 1916 invented the word 'mondialisation', the Belgian internationalist visionary Paul Otlet, and his closest colleague, the Austrian philosopher and activist Otto Neurath, certainly believed that measurement practices would offer ways to build a new world order, in which boundaries between different systems of mediation would dissolve.[2] But measurement techniques always rely on complex mediations

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[1] Alfred W. Crosby, *The Measure of Reality: The Quantification of Western Society (1250-1600)* (Cambridge: Cambridge University Press, 1997); H. Floris Cohen, *How Modern Science Came into the World: Four Civilizations, One 17th-Century Breakthrough* (Amsterdam: Amsterdam University Press, 2010).

[2] Vincent Capdepuy, "Au prisme des mots. La mondialisation et l'argument philologique," *Cybergeo* 576 (2011): http://cybergeo.revues.org/24903; Nader Vossoughian, "The Language of the World Museum: Otto Neurath, Paul Otlet, Le Corbusier," in "L'œuvre de Paul Otlet," special issue, *Associations transnationales* 1, no. 2 (2003): 82-93.

between instruments, tools and practices. They are part of ritual systems that are at once communally shared and debatable. It is neither easy nor self-evident to get them to move or work together. One must study these measures' local meanings and find out about the ceremonies and practices that let them act in many different and interconnected worlds. The concern here is to use these stories of mediations and rituals as ways of reflecting on the worldly extension of measurement practices and thence on that of the science of these practices, metrology.

The institutionalisation of standards and discourses on standardisation, not to mention classic tales from history of the exact sciences, have often been taken as weapons of globalisation, in the term's most aggressive sense. But it's also possible to ask about the possibility of something more like a world history, a history that would study, in Roger Chartier's phrase, "les processus par lesquels des références partagées, des modèles imposés, des textes et des biens circulant à l'échelle planétaire sont appropriés pour faire sens dans un temps et en lieu particuliers".[3] It is no coincidence that in his commentary on history at the global scale, Chartier also asked whether this history "must be a new form of the comparativism as proposed by Marc Bloch in 1928?"[4] Here it's again a question of connecting Bloch's approaches to the rituals of measurement and conceptions of the universe with the possibilities of a world history of science.

Ceremonies of measurement have much to teach us about the importance of placing measurement within a world history of science, a history that would no longer assume an inevitable asymmetry between Europeans' quantitative reason and other peoples' qualitative enterprises. Consider the measurements commonly carried out by Pacific mariners in the later eighteenth century, a moment when quantitative techniques for longitude determination at sea were celebrated as signs of triumphant western modernity, a moment when concern with the "planetary scale" was at the centre of scientific and navigational enterprises.[5] Historians of these ocean surveys

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[3] Roger Chartier, "La conscience de la globalité (commentaire)," *Annales HSS* 56, no. 1, (2001): 119-123, here p. 123.

[4] Ibid., 119; see also Marc Bloch, "Pour une histoire comparée des sociétés européennes," *Revue de synthèse historique* 46 (1928): 15-50.

[5] Marie-Noëlle Bourguet and Christian Licoppe, "Voyages, mesures et instruments. Une nouvelle expérience du monde au Siècle des lumières," *Annales HSS* 52, no. 5 (1997):

have argued that such measurement "was mathematical and uncommunicative", and that navigators such as James Cook "trusted techniques and instruments rather than people who had no particular reason to trust him".[6] According to these historians, maps made on surveys of the northeastern Pacific in the 1790s "framed a distinctively British and scientific domain" through an impersonal calculus of instruments and measurements.[7] Yet these projects were simultaneously absorbed in ceremonial forms of social interaction. Whenever a marine chronometer was used to determine longitude at sea, the triple locks that sealed its ceremonial container had simultaneously to be opened by three different officers, its rate of going ritually marked, its status sacralised. "Our trusty friend the watch", so Cook named it.[8] Very often instruments acquired personal names that made their makers and users present even as they were at work in measurement.[9] There was a social system linking persons and devices in a very complex web of ceremony and politesse.

Such instruments were often taken by the islanders: but we also need to understand what the islanders took them to be. On the Alaskan coast in June 1791, Spanish astronomers who'd reached there from Acapulco built an observatory to orient themselves. Tlingit people led by their chief Xune approached the observatory, which became the privileged site of barter. The expedition's commander recorded in his log that

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1115-51; Vincent Jullien, ed., *Le calcul des longitudes. Un enjeu pour les mathématiques, l'astronomie, la mesure du temps et la navigation* (Rennes: PUR, 2002); Philippe Despoix, *Le monde mesuré. Dispositifs de l'exploration à l'âge des Lumières* (Geneva: Droz, 2005).

[6] Nicholas Thomas, *Discoveries: The Voyages of Captain Cook* (London: Allen Lane, 2003), 7.

[7] Daniel W. Clayton, *Islands of Truth: The Imperial Fashioning of Vancouver Island* (Vancouver: UBC Press, 2000), 198.

[8] John C. Beaglehole, ed., *The Journals of Captain James Cook on his Voyages of Discovery*, vol. 3, *The Voyage of the* Resolution *and the* Adventure, *1772-1775* (Cambridge: Cambridge University Press, 1961), cxii.

[9] La fiabilité d'un instrument en voyage dépendait énormément de la réputation et de la qualité du fabricant, si bien qu'on lui attribuait son nom : un quart de cercle est ainsi nommé un « Bird » ou « Ramsden », une garde-temps « Bréguet » ou « Kendall ». L'on jugeait la valeur et l'utilité de l'instrument par cette éponymie.

> *I do not know whether any of the many natives who approached the observatory understood the religious ideas concerning the Sun by which I attempted to give some colour to our astronomical observations.*[10]

Some encounters were the occasion of surprising and important ritual practices. When the eminent hydrographer and administrator Claret de Fleurieu put together a long account of a 1792 Pacific fur trade voyage, he was able to identify the Îles Marquises using a chart originally made for Cook by a Polynesian navigator, Tupaia:

> *No doubt the precision of the charts of Cook or La Pérouse is not to be demanded from an Islander who navigates with no way of measuring the speed of his course, with no instrument to observe latitude. It must not be forgotten that he has no accurate idea, no comparative measure of distance.*[11]

But Claret de Fleurieu nevertheless had faith in "the accuracy of Tupaia's hydrography", much more than in that of French seamen, whom he castigated for the ignorance of the proper rituals of maritime measurement. They ignored the measurement practices of marine chronometers and lunar tables: "it is time to take French navigators away from the humiliating apathy that keeps them in the chains of ancient routine".[12] The inversion was thus complete: a reliably exact Polynesian, hopelessly traditional Frenchmen.

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[10] Andrew David, Felipe Fernandes-Armesto, Carlos Novi and Glyndwr Williams, eds, *The Malaspina Expedition 1789-1794: The Journal of the Voyage by Alejandro Malaspina* (London: Hakluyt Society, 2001-2004), 2:117 and 133; see Frederica de Laguna, *Under Mount Saint Elias: The History and Culture of the Yakutat Tlingit* (Washington: Smithsonian Institution Press, 1972), 144 and 151.

[11] Charles-Pierre Claret de Fleurieu, *Voyage autour du monde pendant les années 1790, 1791 et 1792 par Étienne Marchand* (Paris: Imprimerie de la République, 1797-1799), 1:268.

[12] Ibid., 1:270 and 2:514; Odile Gannier, "Consigner l'événement : les journaux du voyage de Marchand (1790-1792) et les *Isles de la Révolution*," *Annales historique de la Révolution française* 320 (2000): 101-20; Glyndwr Williams, "Tupaia: Polynesian Warrior, Navigator, High Priest—and Artist », in *The Global Eighteenth Century*, ed. Felicity A. Nussbaum (Baltimore: Johns Hopkins University Press, 2003), 38-51.

This kind of inversion of presuppositions, if not prejudices, with respect to the distinction between tradition and reason, has become rather commonplace among histories of science that take seriously the way pratices are located in specific contexts. Historians of science are concerned with techniques' mediations at moments of encounter and exchange between different kinds of sociability. Measurement seems transcendent, no doubt, and thus capable effortlessly of universal mobility, solely and precisely because it seems not to depend on ordinary resources, at once reliable and fragile, such as instruments made of metal, wood or paper, or on humble practitioners such as sailors, merchants and workmen. Historians of the sciences have thus shown that measurement practices and values are local and mundane. They don't depend on especially inspired or on excessively rational methods.[13] They rely on the situated work of persuasion and credibility. Measurement draws on and reinforces specially organised places where this labour is performed and between which it is distributed.

Such claims point towards problems of delocalisation. How do measures that work in such locales work anywhere else and in principle everywhere else? One key technique is *calibration*. A measurement device must be calibrated before it can be put to work. Calibration puts scales on an instrument by exposing it to a well-known signal, then marking its responses. The crucial assumption is that the device will be able to measure unknown variables if, and only if, these variables are in relevant respects the same as the signal used to calibrate the instrument.[14] A balance, a sextant or a thermometer works on the assumption that unknown entities have gravitational, optical or thermal properties just like those used to calibrate the instrument. This assumption is a form of *social regulation*, because it is a shared convention that governs how collective measurement proceeds and allows new ways of engaging with the world.[15] When measures are in trouble, these shared conventions suddenly became apparent. These conventions thus define *an entire world and its boundaries*, since they stipulate in advance what kinds of phenomena can be measured, and thus known.

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[13] See Simon Schaffer, *La fabrique des sciences modernes, XVII^e^-XIX^e^ siècle*, trad. F. Aït Touati, L. Marcou and S. Van Damme (Paris: Éd. du Seuil, 2014), 8.

[14] Harry M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage, 1985), 100-106.

[15] Dominique Pestre, *À contre-science. Politiques et savoirs des sociétés contemporaines* (Paris: Éd. du Seuil, 2013), 43-57.

The silent trade

In some ways, all measurement practices are rituals, because they demand careful attention to a sequence of performative actions without which the measure loses value. For navigators and assayers, accountants and merchants, the instructions that accompany measurement tools are vital resources, especially when measurements are in dispute. A specific measurement is associated with a specific social setting; and through the mediating work of calibration, measurements accompany conceptions of the universe. In *Les rois thaumaturges*, Marc Bloch's great study of the coming into being and passing away of royal ceremonies of miraculous healing in medieval and early modern England and France, he concluded that "in truth, the idea of the royal miracle was related to an entire conception of the universe".[16] The connexion between the working of the ceremony and the world-view it embodied was clear to Bloch, because he was writing the history of a ritual practice, and at the same time a history of belief in the efficacy of that practice. He understood that the way power is displayed is also a kind of power.

One of the most brilliant historians of money and coinage in medieval and early modern European markets, Bloch showed that measures do not travel very easily. They are bounded by the regimes that simultaneously helped define the properties of reliable knowledge makers and the contents of the world. And these definitions were just as fragile as the extension of this social mode.[17] That is why we need to abandon ethnocentric histories of measurement's progress. Yet, especially in stories of the rationalist triumphs of modern sciences, measurement practices have often been understood as amongst the most powerful ways in which societies become more homogeneous and in which different societies can effectively communicate with each other and dominate them. There is a very long tradition that associates measures as the most effective way of *delocalising* social difference. According to historians of

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[16] Marc Bloch, *Les rois thaumaturges. Étude sur le caractère surnaturel attribué à la puissance royale particulièrement en France et en Angleterre* (Paris: Gallimard, [1924] 1983), 385.

[17] Marc Bloch, "Le problème de l'or au Moyen Âge," *Annales d'histoire économique et sociale* 5, no. 19 (1933): 1-34; Bloch, *Esquisse d'une histoire monétaire de l'Europe* (Paris: Armand Colin, 1954); André Burguière, *L'école des* Annales. *Une histoire intellectuelle* (Paris: Odile Jacob, 2006), 121-24.

ancient commerce, for example, because of "the interweaving of the economic and the social", it was extremely hard to set up agreed connexions around values between communities with contrasting social structures: so it was essential to define measures as autonomous and transcendent.[18] In the fourth book of his *Histories*, Herodotus tells of a land "beyond the pillars of Hercules" where Carthaginian merchants engaged in a strange but reassuring gold trade. These travelling merchants

> *… unload their cargo; then having laid it orderly along the beach they go aboard their ships and light a smoking fire. The people of the country see the smoke, and coming to the sea they lay down gold to pay for the cargo and withdraw away from the wares. Then the [Carthaginians] disembark and examine the gold; if it seems to them a fair price for their cargo, they take it and go their ways; but if not, they go aboard again and wait, and the people come back and add more gold till the shipmen are satisfied. Herein neither party (it is said) defrauds the other; the [Carthaginians] do not lay hands on the gold till it matches the value of their cargo, nor do the people touch the cargo till the shipmen have taken the gold.* [19]

This classical tale of mute and fair barter lasted millennia, even if its location was never entirely fixed.[20] In the thirteenth and fourteenth centuries, Muslim scholars relayed stories from Mali and other West African kingdoms that inland gold producers, summoned by drums, would silently negotiate with Moorish traders from the north. The Venetian navigator Alvise da Cadamosto, in Portuguese service off

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[18] Laetitia Grassin and Raya Ben Guiza, "Les mécanismes institutionnels du commerce extérieur dans l'antiquité : le cas de Carthage," *Antiquités africaines* 38-39 (2002-2003): 345-54, here p. 350.

[19] Herodotus, *The Persian Wars* 4.196, trans. A. D. Godley (Cambridge, MA: Harvard University Press, 1921), 2:399. See: Philip J. Hamilton Grierson, *The Silent Trade: A Contribution to the Early History of Human Intercourse* (Edinburgh: William Green, 1903), 47-48; Émile-Félix Gautier, "L'or du Soudan dans l'histoire," *Annales d'histoire économique et sociale* 7, no. 32 (1935): 113-23, here p. 118-19; Lars Sundström, *The Exchange Economy of Pre-Colonial Tropical Africa* (London: Hurst, 1974), 22-31; Rainer Ertel, "'Stummer Handel' in ökonomischer Sicht," *Zeitschschrift für Ethnologie* 106, no. 1/2 (1981): 93-98, here p. 95.

[20] Timothy Garrard, "Myth and Metrology: The Early Trans-Saharan Gold Trade," *Journal of African History* 23, no. 4 (1982): 443-61, here p. 444.

Senegal in 1455-6, recorded that a silent trade flourished in the interior. Many in Mali reckoned the gold producers might even be born dumb.[21] Cadamosto's story, backed with Herodotean authority, spread widely through Dutch, French and British commercial networks in the seventeenth century. The mariner Richard Jobson, on the Gambia river in 1620, then persuaded to publish his stories by the London cleric Samuel Purchas in 1623, gave familiar tales of a silent trade of salt for gold: "it is said, they have a just manner of trading and never see one another".[22] Guinea became during the seventeenth century a principal source of the precious metal and a scene of competitive commerce between European traders in complex negotiations with the Akan peoples of the region.[23] It was well known to the Europeans that the Akan did not control the origin of all this gold. According to the Basel surgeon Samuel Brun in 1614,

> *... a hut stands there in which the goods remain until the frontier people come to carry them away and lay the gold in little bowls in their place. When they are gone, the Akanists come, take the gold and go home again. Thus the Akanists do not see the traders who give them the gold for the goods. It is a great wonder that neither side deceives the other.* [24]

Hence the significance of stories of silent, reliable, immediate, trade taking place somewhere upcountry. Michael Hemmersam, a Nuremberg goldsmith in Guinea in 1639, claimed they "trade with them without them seeing each other for they imagine

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[21] Paulo Fernando de Moraes Farias, "Silent Trade: Myth and Historical Evidence," *History in Africa* 1 (1974): 9-24, here 11-14.

[22] Richard Jobson, *The Golden Trade, or A Discovery of the River Gambra and the Golden Trade of the Aethiopians* (London: Nicholas Bourne, 1623), 102-103; Edward W. Bovill, "The Silent Trade of Wangara," *Journal of the Royal African Society* 29, no. 113 (1929): 27-38, here p. 31-33.

[23] Timothy F. Garrard, *Akan Weights and the Gold Trade* (London: Longman, 1980), 71-80; Yann Deffontaine, *Guerre et société au royaume de Fetu, Efutu. Des débuts du commerce atlantique à la constitution de la fédération fanti : Ghana, Côte de l'or, 1471-1720* (Ibadan/Paris: IFRA/Karthala, 1993), 53-57.

[24] Cited in Adam Jones, ed., *German Sources for West African History, 1599-1669* (Wiesbaden: Franz Steiner, 1983), 67 and 89-90. See also de Moraes Farias, "Silent Trade," 18.

they might die". Whether it was because they were secretive, or hideous, or congenitally mute, "the Negroes take it away and leave as much Gold. They are the truest dealing men in the world. I have not found so much faith, nor faithfulness, no not in Israel".[25]

Despite, or perhaps precisely because of, its mythic status, the story of the silent trade in African gold launches these reflexions on ceremonies of measurement. The silent trade was defined by the principles that the parties never met nor relied on any intermediary or overseer: it was believed that shared measures existed, even while the parties remained invisible and mute. Its history long functioned as the ideal type of the most primitive stage of commerce, a 'utopian model' of reliable measures produced without any mediation.[26] According to Emile Durkheim, for example, 'it might be asked whether markets are not the organized version of these initial exchanges" between parties "taboo for each other".[27] Stories gathered worldwide, from the Gold Coast and the Silk Route, western Africa in 1455, Newfoundland in 1612, or Ceylon in 1681, were used to underwrite a quasi-evolitionist model according to which the silent trade was seen by sociologists as "a preparation for exchange", if not 'the archetype of all exchange'.[28] Shared measures were allegedly easily establishment by the immediacy of things whose calibration had already happened, not by the mediation of some social interaction. It was imagined that the ceremonies of measurement came before any social institution yet, in the end, managed to generate such institutions. Some earlier twentieth century scholars,

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[25] Jones, *German Sources*, 116. Cf. Luke, 7:9 and Matthew 8:10.

[26] Stephen Greenblatt, *Marvelous Possessions: The Wonder of the New World* (Chicago: University of Chicago Press, 1991), 182n34.

[27] Émile Durkheim, review of Grierson, *The Silent Trade*, in *L'année sociologique* 8 (1903/1904): 483-86, here p. 485.

[28] René Maunier, "Recherches sur les échanges rituels en Afrique du Nord," *L'année sociologique*, n.s. 2 (1924-1925): 11-97, here p. 16; Georges Smets, "Le commerce silencieux," *Bulletin de la classe des lettres et des sciences morales et politiques de l'Académie royale de Belgique*, 5th ser., 25 (1939): 119-31, here p. 122 (Ceylon); David Harris Sacks, "The Blessings of Exchange in the Making of the Early English Atlantic," in *Religion and Trade: Cross-Cultural Exchanges in World History, 1000-1900*, ed. Francesca Trivellato, Leor Halevi and Cátia Antunes (Oxford: Oxford University Press, 2014), 62-90, here p. 73-76 (Newfoundland).

therefore, sought the original strength of the market in these stories of the silent trade. In reply, their opponents observed that "it is very unlikely that such conventions could have been set up between people who did not already know of self-conscious and calculated exchange".[29] This trade could also be linked with the ancient and very widespread distrust of merchant-travellers, often seen as hostile and foreign to the social order. It was said that the silent trade and its original measures thus less to more advanced systems of values.[30] Ethnographic and historical research has dramatically challenged the very existence of the silent trade as a cultural reality. Nevertheless, a system of measures of great trustworthiness and faithfulness which did not seem to depend on any social network nor any system of mediation, which in some way or another worked everywhere and anywhere, sustained the idea that measures express natural facts rather than socio-historical conditions. [31]

If the silent trade ever took place, which is doubtful, it happened at sites of critical significance in world trade and exploitation.[32] In fact, the Guinea trade relied on exquisitely ingenious measurement systems, the magnificently crafted gold weights designed by Akan traders to measure out variable amounts of gold dust in the highly fraught transactions they conducted with European intermediaries. Very often, indigenous traders used weights whose size varied with the social status of their trading partners, and gold dust was for them the medium of exchange, not an

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[29] Smets, "Le commerce silencieux," 124. See also: Grierson, *The Silent Trade*, 64-67, 87-88; Bovill, "The Silent Trade," 34-35.

[30] Karl Polanyi, "Ports of Trade in Early Societies," *Journal of Economic History* 23, no. 1 (1963): 30-45, here p. 34; Jean-Christophe Agnew, "The Threshold of Exchange: Speculations on the Market," *Radical History Review* 21 (1979): 99-118; James Redfield, "The Development of the Market in Archaic Greece," in *The Market in History*, ed. A. J. H. Latham and B. L. Anderson (London: Croom Helm, 1986), 29-58, here p. 38-41.

[31] Sundström, *The Exchange Economy*, 31 ("No first hand evidence of the silent trade exists"); de Moraes Farias, "Silent Trade," 10 and 19; Philip D. Curtin, *Cross-Cultural Trade in World History* (Cambridge: Cambridge University Press, 1984), 12-13; Wilfred Dolfsma and Antoon Spithoven, "'Silent Trade' and the Supposed Continuum between Oie and Nie," *Journal of Economic Issues* 42, no. 2 (2008): 517-26, on p. 524 ("the silent trade never existed").

[32] Pierre Vilar, *Or et monnaie dans l'histoire, 1450-1920* (Paris: Flammarion, 1974), 63.

independent commodity.[33] Europeans criticised the Guinean traders, both because the Akan did not seem to understand that gold came originally from God, and also because the Akan imagined gold was the Europeans' God.[34] Somehow, these Europeans managed simultaneously to acknowledge the cunning agility with which the Akan manipulated weights in measurement, while at the same time insisting that the source of Guinea gold was dominated by a pervasive silent trade.

The tale of the silent trade was widespread in the markets of early modern Europe. The Anglo-Irish satirist and clergyman Jonathan Swift, for example, was obsessed with Guinea gold, and familiar with some of these sources. The stories were available in his own library in texts such as Purchas' *Hakluytus posthumus* (1625), which he used in the composition of *Gulliver's Travels*.[35] Gulliver encounters professors at the Lagado Academy's language school who use things to limit the damage speech does to the lungs, for "since words are only names for things, it would be more convenient for all men to carry about them such things as were necessary to express the particular business they are to discourse on". The erudite would carry bulging sacks of things with which to converse, while salons would be aptly stocked with "all things, ready at hand, requisite to furnish matter of this kind of artificial converse".[36] And this silent trade would promote a universal language of things to ease communication between nations of different tongues. The silent trade is simply a way of assuming that calibration is not a local set of conventions, but a vast and universal system of immemorially absolute values.

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[33] Garrard, *Akan Weights*, 93 and 174-75; André Nitecki, *Equal Measure for Kings and Commoners: Goldweights of the Akan from the Collections of the Glenbow Museum* (Calgary: Glenbow Museum, 1982), 26; G. Niangoran Bouah, *L'univers Akan des poids à peser l'or*, vol. 3, *Les poids dans la société* (Abidjan: Nouvelles éditions africaines, 1984-1985), 18-22.

[34] Pieter de Marees, *Description and Historical Account of the Gold Kingdom of Guinea*, trans. Albert van Dantzig and Adam Jones (Oxford: Oxford University Press, [1912] 1987), 73 and 191.

[35] Dirk Passmann, "Purchas and Swift: Where Horses Talk and Eagles Carry Men," *Notes and Queries* 31, no. 3 (1984): 390-91; Arthur Sherbo, "Swift and Travel Literature," *Modern Language Studies* 9, no. 3 (1979): 114-27.

[36] Jonathan Swift, *Travels into Several Remote Nations of the World by Lemuel Gulliver*, 2 vols., (London: Benjamin Motte, 1726), 2:76-77.

No doubt the utopia Swift satirized here is that of a world in which measurements can travel without mediators. The myth of the silent trade especially stressed that such commerce was preternaturally honest, and (despite gross evidence to the contrary) never needed local agents. It has been common to associate the Lagado way with things with Swift's attack on the early Royal Society, its dreams of a science of universal measures and inventory accumulation. The Royal Society was seen as the twin sister of the Royal Africa Company, main agent of the slave trade. This satire also emerges rather directly from the Anglo-Irish experience of monetary crises in the measure of values.[37] The silent trade helps bring out an important aspect of what was at stake in Swift's joke. In Lagado, the professors evidently assign too much and the wrong kinds of agency to things. They imagine, falsely, that things can communicate their values without go-betweens, and that things have embedded within them innate powers to guarantee measures.

This is *fetishism*: just as the concept of the silent trade – immediate communication by things – developed in Guinea, so, as William Pietz has splendidly demonstrated, Guinea was the location of the fetish – the false attribution of power to things that lack this power. 'Fetishes' had once referred to worship of the wrong kind of thing. Now they referred to the worship of any kind of material artifact.[38] Andreas Ulsheimer, a Swabian protestant surgeon, in Guinea 1603-4, reported that

> *... just as the Papists annually on Corpus Christi day go around their fields and bless them against storms, so the Guineans annually gather together in each and every village on a certain day in April and make their fetish or devil-images to honour their fetish or false god, the Devil. These images are nothing but a heap of dirt squeezed together.*[39]

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[37] Gregory Lynall, *Swift and Science: The Satire, Politics and Theology of Natural Knowledge, 1690-1730* (New York: Palgrave Macmillan, 2012), 89-119; Mark Govier, "The Royal Society, Slavery and the Island of Jamaica, 1660-1700," *Notes and Records of the Royal Society of London* 53, no. 2 (1999): 203-17.

[38] William Pietz, "The Problem of the Fetish, II: The Origin of the Fetish," *Res: Anthropology and Aesthetics* 13 (1987): 23-45; Michèle Tobia-Chadeisson, *Le fétiche africain. Chronique d'un "malentendu"* (Paris: L'Harmattan, 2000), 79-88.

[39] Jones, *German Sources*, 36.

Nicolas Villault, a French trader who reported on Guinea in 1669, described such fetishes as 'choses inanimées, et le plus souvent si sales et vilaines, qu'on ne voudrait pas les toucher'.[40] In particular, fetishes named things *privileged in another's culture* which measurements in one's own culture could unmask as *mere lumps of matter*. Under this approach, it would be claimed that commodified things could be exchanged across any social boundary without changing their true value. So they could be used to judge others against an apparently universal standard.

The roots of measurement

This tale of a decisive shift from local ceremonies to global sciences, whose measures work anywhere and in principle everywhere, has since dominated the history of the measurement. Consider the splendid histories of the move from "le monde de l'à peu près à l'univers de la précision", the title of a remarkable essay by Alexandre Koyré in 1948 as part of a series of articles on "le machinisme". According to Koyré, past societies failed to achieve technological modernity because they lacked the sense that the world could be precisely measured. "Ce n'est pas le thermomètre qui manque, c'est l'idée que la chaleur soit susceptible d'une mesure exacte'".[41] Koyré reckoned regimes of calibration were responsible for the emergence of modernity. What kinds of social systems might allow or prevent the emergence of such an idea of exactitude? Replying to Koyré in *Annales* in 1950, Lucien Febvre had an answer: he entirely accepted the assumption that calibration was missing from earlier societies, and added that what mattered was a reliance on testimony instead of immediate measurement. "Le monde de l'à peu près, oui. Mais ce n'est point assez dire. Royaume de ouï-dire, non moins". According to Febvre, savants' reliance on the credit of others' stories long barred the institutionalization of a strong sense of what was possible, and what was impossible, in nature.[42]

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[40] Nicolas Villault, *Relation des costes d'Afrique, appellées Guinée* (Paris: Denys Thierry, 1669), 262.

[41] Alexandre Koyré, "Du monde de l'à peu près à l'univers de la précision," *Critique* 4, no. 28 (1948): 806-23, here p. 814.

[42] Lucien Febvre, "De l'à peu près à la précision en passant par ouï-dire," *Annales ESC* 5, no. 1 (1950): 25-31, here pp. 30-31.

But there is something misleading about an easy identification of the practices of precision measurement with a Weberian account of rationalization and disenchantment. Spectacular examples are furnished by measurement rituals performed by pilgrims to Jerusalem, as the historian Zur Shalev has demonstrated. The Temple of Solomon and other sacred sites were understood as embodiments of precision measures. Pilgrims were provided with length standards to calibrate their bodies against the holy sites' dimensions, some printed in their guidebooks. Cords measured carefully against such holy places were then used as cures of bodily suffering. A vast number of seventeenth century texts included detailed plans of the Temple and other sacred sites: European cities were filled with scale models of exquisite precision designed to display divine measures.[43] Ritual practice, royal and divine power, and the activities of measurement and exchange were linked. This was especially the case during the great struggles around the 'moral economy' of agrarian society, in E.P.Thompson's memorable formulation, struggles in which the rituals of grain measures became the site of conflicts about calibration, standards and the economy.[44] These aggressive ceremonies of measurement complement what Michèle Fogel has astutely called "cérémonies de l'information", the rituals through which the early modern state produced information through the exercise of power.[45] It may have been tempting for Koyré and his colleagues, great historians of the long-term transition to modern sciences, to suppose that the history of measurement involved a late but inexorable move from the local to the universal. Yet there must instead be ways in which local regimes of ritual measurement and the global delocalisation of measurement have always been entangled with each other.

Historians of the sciences have always been obsessed by problems of incommensurability and impressed by the ways in which specific sets of scientific practices embody specific worldviews. What if we take the term *incommensurability* more literally? The now-classic 1970 study of the social meaning of measurement

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[43] Zur Shalev, "Christian Pilgrimage and Ritual Measurement in Jerusalem," in "La misura," special issue, *Micrologus* 19 (2011): 131-150.

[44] Edward P. Thompson, *Customs in Common: Studies in Traditional Popular Culture* (London: Merlin, 1991), 252-55 .

[45] Michèle Fogel, *Les cérémonies de l'information dans la France du XVI^e^ au XVIII^e^ siècle* (Paris: Fayard, 1989).

institutions, *Les mesures et les hommes*, written by Witold Kula, another great medievalist much admired by Bloch, appeared in a French edition exactly three decades ago under the aegis of Krzystof Pomian.[46] Kula's book starts with coments on the historic links between the development of metrological systems and socio-economic conditions. For west African gold traders, he stated, 'dont l'économie est fondée sur l'exploitation des sables aurifères, c'est le système des poids qui est très poussée'.[47] Kula's detailed analysis of European cultures' passage from traditional, embodied measures to abstracted, universal metric systems, charted the dehumanising drive for objectivity, and found its key moment in Revolutionary France. According to Kula, for the metre's final victory, two conditions had to be satisfied: "l'égalité devant la loi; l'aliénation de la marchandise".[48] The politics of reason and of the commodity are unmistakable. Kula ended his work with a "post-scriptum en homage aux préfets ." Against Chateaubriand's post-Revolutionary assault on the "tyranneau" of the metric Jacobins, Kula sang the praises of the measured state:

> *Les préfets […] tenteront et parviendront à unifier d'autres categories de pensée des hommes soumis à leur administration. Dans leurs efforts, il auront encore beaucoup de succès. Ils réussiront […] jusqu'à ce que vienne un jour où nous nous comprendrons tellement bien que nous n'aurons plus rien à nous dire.*[49]

This utopian vision of the silent trade has not yet quite been reached. Already, in a 1960 essay in *Annales*, Kula argued that since "la chute brutale de la domination politique européenne sur le monde a eu pour corrolaire l'adoption par le monde entier du modèle social créé par cette même Europe," and that since "le problème fondamental de notre époque est celui de l'unification de la planète dans les cadres de la civilization industrielle", it followed that "le devoir de l'histoire consiste à interroger le passé dans le dessein de découvrir ce qui nous a conduit à cette

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[46] Jean-Claude Hocquet, "Les mesures ont aussi une histoire," *Histoire et mesure* 1, no. 1 (1986): 35-49, here p. 35-36.

[47] Witold Kula, *Les mesures et les hommes*, trans. J. Ritt (Paris: Éd. de la MSH, [1970] 1984), 11.

[48] Ibid., 119-20.

[49] Ibid., 277.

unification".[50] Did he suppose that measurement's path was secured forever? Probably not, though this has often been the ritualists' dream, notably in the Revolutionary culture Kula lauded, and of which Mona Ozouf has so brilliantly explored the sacrificial and utopian ceremonies.[51]

In some rituals of sacred power, what was at stake was the measured exchange of different commodities. While Febvre found the roots of modern precision in the displacement of a social practice of trust by that of immediate engagement with the rituals of measurement, other social scientists urged the ritual origins of measurement practices themselves. Instead of supposing that social order was achieved through the power of precision techniques, several anthropologists and mathematicians argued that the grip of measures was the result of a globally diffused system of rituals. Early twentieth century classical scholars and comparative anthropologists such as James Frazer, Jane Harrison and Arthur Hocart argued for a closely complementary relation between myth and ritual. The eminent American mathematician Abraham Seidenberg and others then used this approach to seek the ritual origins of measurement. They argued that in primordial creation rituals, designed to guarantee fertility and plenty, principal participants ran the risk of being sacrificed and killed. These rituals were thus absolutely necessary, but also rather dangerous. So sacrificial protagonists would appear in the ritual as an equivalent token, rather than in person. Pebbles or coins, for example, would be used as substitutes for the sacrificed participant.[52]

This explained, so it was claimed, why in so many cultures there was a strong taboo on counting persons directly. 'When thou takest the sum of the children of Israel after their number', so Moses is instructed in *Exodus* ch.30, 'then shall they give every man a ransom for his soul unto the Lord, when thou numberest them; that there be no plague among them, when thou numberest them'. Kula recorded a host of plebeian and peasant forms of distrust of counting and measuring, classing them as

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[50] Witold Kula, "Histoire et économie : la longue durée," *Annales ESC* 15, no. 2 (1960): 294-313, here p. 313.

[51] Mona Ozouf, *La fête révolutionnaire 1789-1799* (Paris: Gallimard, 1976).

[52] Abraham Seidenberg, "The Ritual Origin of Counting," *Archive for History of Exact Sciences* 2, no. 1 (1962): 1-40; Robert Ackerman, *The Myth and Ritual School: J. G. Frazer and the Cambridge Ritualists* (New York: Routledge, [1991] 2002), 89-118.

"superstitions" about the power of the census and of the balance.[53] A mass of ethnographic evidence on ceremonies of weighing the soul, from classical sources and from early modern central Europe, was accumulated by the mid-twentieth century Austrian ethnographer Leopold Kretzenbacher. All this evidence was also used to urge the importance of the balance as a key part of this substitution ritual. Such instruments were claimed to be ceremonial ways of establishing a reliable equivalence between the protagonist to be sacrificed and the offering made in the participant's stead. It was concluded that these rituals were principally embodied in such basic and ancient measurement activities as the balance, the census and the fiscal system. The divine monarch thus became the agent who calculated taxes as substitute for counting subjects' persons directly.[54]

This remarkable account of the relation between ritual and measurement's origins was explicitly designed to bolster a diffusionist version of cultural anthropology and to counter the claims of modish mid-twentieth century structural functionalism. We will not here pursue the ambitions of this universal ethnography of a globally diffused ritual system, which perhaps tells us more about the history of human sciences than the practices of past measurements. It is nevertheless possible to see how local practices of measurement were tied up with specific ceremonies of offering and sacrifice. In forging his account of the relation between ritual practice and royal power, Bloch explicitly engaged with the work of James Frazer and his peers. In 1922 Frazer was presented with an honorary doctorate at Strasbourg, Bloch's university. In his ambitious 1928 programme for comparative history, Bloch discussed the common approach, adopted both by enlightenment philosophers and by Frazer, which saw societies spatially remote from European modernity elsewhere on Earth as comparable with those of primitive peoples.[55] In his brilliant 2010 Marc Bloch lecture, Carlo Ginzburg rightly emphasized that "avant de rejeter la

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[53] James George Frazer, *Le folklore dans l'Ancien Testament*, trad. E. Audra (Paris: Paul Geuthner, [1919] 1924), p. 267-71; Seidenberg, "The Ritual Origin of Counting," 19-20 ; Kula, *Les mesures et les hommes*, 21-25.

[54] Abraham Seidenberg and James Casey, "The Ritual Origin of the Balance," *Archive for History of Exact Sciences* 23, no. 3 (1980): 179-226.

[55] François-Olivier Touati, *Marc Bloch et l'Angleterre* (Paris: Boutique de l'histoire, 2006), 83-84; Marc Bloch, "Pour une histoire comparée des sociétés européennes," *Revue de synthèse historique* 46 (1928): 15-50, here p. 18.

comparaison ethnographique, qu'il associait au nom de Frazer, Bloch l'examinait comme une alternative légitime".[56] For Frazer as for enlightenment philosophers, far away was long ago. Bloch made lengthy manuscript notes designed to explain the faults of Frazerian method. He carefully distinguished Frazerian comparative ethnography from "l'histoire comparée à horizon restreint", where it was a question of tracing ritual practices in societies often in close contact with each other.[57] In *Les rois thaumaturges* he made the point very clear: "ne transportons pas les Antipodes tout entiers à Paris ou à Londres".[58] But we need to understand what happens when such transportation did indeed happen within colonial and world circulations, and how measures were derived from and applied to such remarkable displacements.

Royal rituals

Consider one of Bloch's specific examples of a measurement ritual. Following Jacques Le Goff, Ginzburg pointed out the striking absence from *Les rois thaumaturges* of any reference to the work of Marcel Mauss, whose *Le don* appeared a year after Bloch's book.[59] At the very centre of his study of medieval kingship and ritual healing, Bloch included a striking analysis of an English ceremony that explicitly linked the ceremony of the gift, measurement, balance and royal authority. From the thirteenth century, every Good Friday the English king would creep towards an altar on which stood the cross. At the foot of the altar he would place a quantity of fine gold and silver coins. "Il reprenait ces pieces, les 'rachetait' disait-on, en mettant à leur place une somme équivalente en espèces monnayées quelconques", normally 25 shillings.[60] From the precious metal so exchanged, metal rings were forged which from at least the fifteenth century were treated as curative talismans, especially potent against epilepsy, the sacred disease. According to a fifteenth century writer, the healing power of "l'or et l'argent devotement touchés, selon la coutume annuelle, par

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[56] Carlo Ginzburg, "Lectures de Mauss," trad. M. Rueff, *Annales HSS* 65, no. 6 (2010): 1303-20, here p. 1304.

[57] Bloch, "Pour une histoire comparée," 19n2.

[58] Bloch, *Les rois thaumaturges*, 54.

[59] Jacques Le Goff, preface to Bloch, *Les rois thaumaturges*, xxxv; Ginzburg, "Lectures de Mauss," 1304.

[60] Bloch, *Les rois thaumaturges*, 160.

les mains sacrées, par les mains ointes des Rois d'Angleterre, a été expérimenté par un frequent usage dans un grand nombre de parties du monde".[61]

These cramp rings, as they were called by reference to epilepsy, became an element in English diplomacy. In 1510 the English ambassador to emperor Charles V asked for cramp rings to be sent from London to the Habsburg ruler. Five years later a Genoese spy working in Paris asked for a dozen rings to sell to wealthy Frenchmen, while the English ambassador in France claimed that Parisians had offered him twice their worth for these blessed rings.[62] But at the accession of Elizabeth I in 1558, the entire ceremony of ritual exchange and blessing ceased. Instead, English people started to make rings for themselves, and for the medical marketplace. According to Bloch, "une opération de nature en quelque sorte juridique formait le noeud de l'action: l'offrande des pieces d'or et d'argent et leur rachat moyennant une somme équivalente".[63] Just as comparative ethnographers argued that the ritual of the balance had emerged from the need to establish a ceremonial equivalence between the sacrificial victim and the substituted offering, so, according to Bloch, "pour que l'offrande ait quelque sérieux et, partant, quelque efficacité, on ne reprendra le don qu'en payant, comme lorsqu'on achète une chose à son légitime propriétaire".[64] However, secondly, Bloch explained how the English monarchs had seized power over the ceremony, by making themselves the masters of the rings' efficacy. From the sixteenth century, the rings were made beforehand, their powers attributed solely to ritual contact between the rings and the monarch's anointed hands. The system of ritual equivalence was abandoned or forgotten. With this power grab by the monarchy, the sacred metal could no longer be considered as subject to a process of measurement: "l'antique pratique du faux don et faux rachat n'était plus guère comprise".[65] So the ritual's politics changed through a change in the administration of

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[61] Raymond Crawfurd, "The Blessing of Cramp-Rings: A Chapter in the History of the Treatment of Epilepsy," in *Studies in the History and Method of Science*, ed. Charles Singer (Oxford: Clarendon Press, 1917-1921), vol. 1, 165-188, here p. 171.

[62] Bloch, *Les rois thaumaturges*, 325.

[63] Ibid.,169.

[64] Ibid.,171.

[65] Ibid., 180.

measurement; then, after the abandonment of the entire ritual by the English crown, the rings became a commercial commodity, made by subjects and marketed globally.

Bloch's astute analysis of the ceremony of cramp rings highlights the roles that rituals of measurement could play in the work of politics and of public knowledge. He focused especially on changes in what might be called *trials of strength* in which the staging of a relation of equivalence was connected with the display of forms of official power. The quantitative experimental method, which Koyré and Febvre saw as a major achievement of early modernity, and as a decisive break with earlier traditions of ritual performance, nevertheless emerged from these rather public ceremonies. The importance of the balance and of body techniques in this set of practices was decisive. As Bloch pointed out, the English monarchy exploited and transformed a ceremony of miraculous measures by displacing attention from the work of balanced exchange towards the presence of sacred bodies. Habsburg monarchs were invested in these kinds of transformations. Charles V set up a public balance where those accused of dealing with the devil could be weighed, then issued with a certificate of moral cleanliness. In the early seventeenth century, his grandson Philip III gave four times his weight in gold, and seven times his weight in silver, as an offering for the survival of his ailing son.[66] In institutions such as churches, mints, academies and courts, public assays simultaneously dramatized a moral order and a measure of command over the powers of nature and the state.

The royal rite of weighing the body as an element in assays of monarchical power and moral order were not at all limited to European kingships. They were familiar within orientalist stories through the long tradition of south Asian rulers whose bodies were balanced against a range of precious commodities. From as early as the Gupta period, during the fourth century CE, monarchs would be weighed against precious metals and the proceeds given away as gifts to the poor. Very similar customs are testified from Sri Lanka in the early eighth century. In the 1500s, just as the Tudors grabbed control of the cramp ring ceremony, so Mughal rulers, keen to identify themselves with perennial traditions of south Asian monarchy, resuscitated and developed these ceremonies, holding twice-yearly large-scale ceremonial

[66] Seidenberg and Casey, "The Ritual Origin of the Balance," 198.

weighings of the monarch's body and charitable offerings, and extending the practice to the ruler's sons and to honoured courtiers.

According to the Persian text of the *Ain-i-Akbari*, composed around 1590 CE by Akbar's eminent advisor Abu'l-Fazl ibn Mubarak, the ruler would be weighed against a range of substances, including gold, mercury, iron, silks, perfumes, drugs and grain, before the great potlatch of ritual gift giving.[67] Very significantly, Abu'l-Fazl began his treatise with nothing less than a long account of coinage, the origin of metals, and the workings of the imperial Mint. Reporting on successive currency reforms by Mughal ministers, Abu'l-Fazl insisted that "the edifice of the world" was based on the successful practices of the fiscal system and its rituals. At the very start of a natural history of the Mughal court's administrative system, he tabulated the specific gravities of a vast range of substances, explained how alloys were smelted and offered a cosmology of metallurgy.[68]

The text, and the ceremonies described there, matched an image of ideal equilibrium between a landed elite and the commercial system reshaped during the sixteenth century. The significance of such ceremonies of alloying and weighing were familiar to the later sixteenth century Portuguese chronicler Fernão Mendes Pinto, who included them in his book of Asian travels.[69] Thomas Roe, English ambassador to Jahangir's court at Agra in 1616-1617, gave very detailed if quizzical accounts of the ritual of Mughal bodily measurement:

> *I understood the emperor's weight to be nine thousand rupees, which are almost one thousand pounds sterling, with gold and jewels, and precious stones, but I saw none: it being in bags, it might be pebbles.*[70]

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[67] Abū al-Faẓl ibn Mubārak, *Ayeen Akbery, or the Institutes of the Emperor Akber*, 3 vols., ed. and trans. Francis Gladwin, (Calcutta: 1783-1786), 1:279.

[68] Ibid., 1:50-54. Cf. Da. 5-8.

[69] Muzaffar Alam et Sanjay Subrahmanyam, "L'état moghol et sa fiscalité, XVI^{e}-XVIII^{e} siècles," *Annales HSS* 49, no. 1 (1994): 189-217, here p. 197-98; Seidenberg and Casey, "The Ritual Origin of the Balance," 198.

[70] William Foster, ed. *The Embassy of Sir Thomas Roe to the Court of the Great Mogul, 1615-1619*, 2 vols. (London: Hakluyt Society, 1899), 2:411.

Roe's chaplain, who also witnessed the scene, made the obvious Biblical analogy with the fall of Babylon to the Persians, then drew a politically savvy conclusion:

> *… when I saw Jahangir in the balance I thought on Belshazzar, who was found too light. By his weight of which his physicians keep a yearly account, they presume to guess of the present estate of his body, of which they speak flatteringly, however they think it to be.*[71]

The trope became a commonplace in orientalist accounts of the complex systems of accumulation and trade in south Asia. Thus in his posthumously published *Description des états du Grand Mogol*, François Bernier described Aurangzeb's weighing ceremony in the 1660s,

> *Le troisième jour de cette fête, le roi se fit peser avec beaucoup de cérémonie, et après lui plusieurs omerahs* [c'est-à-dire émirs], *avec de grandes balances et des poids qu'on dit être d'or massif. Il me souvient que tous les omerahs témoignèrent une grande allegresse de ce que le roy pesait deux livres davantage que l'année précédente.*[72]

It was from Bernier, indeed, that in the *Lettres persanes* Montesquieu would then draw his condemnation of royal excess and political tyranny:

> *Quand je vois le Mogol qui, toutes les années, va sottement se mettre dans une balance et se faire peser comme un boeuf; quand je vois les peuples se réjouir de ce que ce prince est devenu plus matériel, c'est-à-dire moins capable de les gouverner, j'ai pitié de l'extravagance humaine.*[73]

Montesquieu's characteristic acuity recognized that such public assays in rituals of measurement had major political significance. "Ce roi est un grand magicien"[74]: the citation from *Lettres persanes* that Bloch chose as epigraph for *Les rois*

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[71] Ibid.

[72] François Bernier, *Voyages de François Bernier contenant la description des États du Grand Mogol*, 2 vols. (Amsterdam: Paul Marret, 1699), 2:55.

[73] Montesquieu, *Lettres persanes* (Cologne: P. Marteau, 1754), 88 (letter 38).

[74] Ibid., 51 (letter 22).

thaumaturges. Montesquieu's reflexivity recognized, too, that despite their exoticism these lessons applied quite directly to European as much as to oriental realms.

Tests of values

To illuminate the roles of such measurement rituals within and between the global trade systems of the epoch, think again about Guinea gold. The Guinea trade combined exchange of gold, where fetishism was evident, and of slaves, where the transformation of persons into things was viciously explicit. The voyage to and from Guinea shows how the silent trade, in which persons who could not understand each other established measurement through things, and superstitious fetishism, in which things that could not make themselves understood were covertly measured through persons, were from the first rather tightly interwoven and occupied the same locations. For English traders, such as the colleagues of Thomas Roe, this gold ended up as a central part of a measurement ceremony entirely comparable with those of cramp rings and the royal touch. At exactly the same moment and in exactly the same sites when these great rituals of kingly power were first institutionalised, the English regime also established measurement ceremonies around the gold coinage manufactured from Guinea metal. The aim was to calibrate the value of gold in circulation, often under threat from fiscal devaluation and informal counterfeiting, through rituals that sanctified the measurement of the coinage.

Linked very closely with the workings of the Royal Mint at the Tower and the centre of royal power in Westminster, the *Trial of the Pyx* was so-named for the box in which randomly selected coin samples were stored before trial. This ceremony was first recorded in the middle of the thirteenth century and held regularly from the fourteenth century. It was thus contemporary with the inauguration of the royal rituals of touching for scrofula and of the manufacture of cramp rings. Indeed, the pyx was originally the box in which wafers were held before the Mass. One coin was selected from each *journée*, each period of production of about fifteen pounds of gold. The pyx was guarded by three locks, as would be common for many similar systems of state security and sacred ritual, including the marine chronometers that accompanied mariners on ocean voyages. The box was supposed to contain a leather bag of coins for each *journée*. Each bag's contents then being weighed, its contents were mixed and tried by fire by a chosen jury of goldsmiths after a solemn and ceremonial oath. A

selection of the trial gold plate against which the minted coins were to be calibrated was put apart and stored in the Chapel of the Pyx in Westminster Abbey.[75]

The Trial of the Pyx was sometimes a moment when the King personally surveyed and evaluated the values made at his Mint. The resemblance between the offerings of coin in the case of the ceremony of the rings and that of the pyx was close. The royal prerogative was made to look like the fount of the entire system of good values. Decisively, this public assay linking the monarch's person with the measurement of metal was designed simultaneously to determine the value of gold coinage and to establish for the public that this gold's value could be trusted by the state. There was an intimate connexion between this ceremony, the Guinea trade, and the development of measures on a world scale. As Pierre Vilar points out in his masterly *History of Gold and Money*, there was a significant coincidence between the currency stabilisation of 1696-1714, a trebling of excise revenue in 1693-1714, and the emergence of trading system linking the Atlantic triangle between Guinea, Brazil and the Caribbean, and the European markets.[76]

At the same period, from 1696, the Mint was managed by Isaac Newton, natural philosopher and servant of the state, especially active at the period of the so-called Great Recoinage. In Mint work he insisted on strict accuracy in weighings and sought to correct what he judged an unacceptably large tolerance of error in the average weight of coins. If the gold pieces tried in the Pyx ritual were too light, the loss was to be made up at the expense of the Mint's master, Newton himself. In 1710, for example, he protested at the quality of the standard with which the goldsmiths compared the gold coins.[77] In Guinea, as in Newtonian London, enormous power was attributed to inanimate substances if and only if they were subject to the right set of measurements. It is no coincidence that the first English narrative with a potent object as its protagonist, a fiction of a thing's life and deeds as key to understanding the

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[75] Simon Wortham, "Sovereign Counterfeits: The Trial of the Pyx," *Renaissance Quarterly* 49, no. 2 (1996): 334-59, here 346-49; Steven M. Stigler, "Eight Centuries of Sampling Inspection: The Trial of the Pyx," *Journal of the American Statistical Association* 72, no. 359 (1977): 493-500, here p. 493-94.

[76] Vilar, *Or et monnaie*, 273.

[77] John Craig, *Newton at the Mint* (Cambridge: Cambridge University Press, 1946), 48-49; Isaac Newton, *Correspondence*, ed. A. Rupert Hall *et al.*, 7 vols. (Cambridge: Cambridge University Press, 1959-1977), 5:82-83.

wider social world, was Charles Gildon's *The Golden Spy*, printed in 1709, whose eponymous protagonist is a guinea coin made of West African gold. Measurement and its ceremonies dominated the public culture of the Newtonian world.[78]

As head of the Mint, Newton was extremely involved in the Pyx trial, the Guinea trade and their various measurement rituals. He worked at a major centre of world commerce and sought simultaneously to ground ritual measurement on a long history of providential cosmology. Newton found the connexion through his vast researches on the dimensions of the Temple of Solomon. He certainly witnessed models of the Temple on show in London and, like Swift, read closely in travelers' tales from Africa and the Levant. He shared the view that the sacred books encoded descriptions of precision rituals under the cover of myths. A detailed analysis of the measurements of the Temple followed, to be published in his writings on the *Sacred Cubit*. He proved the ancients had known the true system of the universe, then celebrated this cosmology through the exact measures of their temples.[79] A history of measurement ceremonies was therefore welded to what the historian Colin Kidd calls 'ethnic theology', the major eighteenth century enterprise to understand the ways in which world networks of commerce and population had apparently become in ancient times a universal social system.[80]

Newton's early eighteenth century efforts to calibrate the values of coined gold in the Pyx ceremony and the dimensions of ancient measurements also corresponded with his exactly contemporary attempts to calibrate measurements gathered worldwide of the length of pendulums, the heights of tides, and the positions of comets and planets. In 1712-1713, for example, Newton and his colleagues were engaged in making a new version of the *Principia mathematica*, in which worldwide

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[78] Charles Gildon, *The Golden Spy, or A Political Journal of the British Nights Entertainments of War and Peace, and Love and Politics* (London: Woodward/Morphew, 1709); Jonathan Lamb, *The Things Things Say* (Princeton: Princeton University Press, 2011), 40.

[79] Jean-François Baillon, "Les écrits sur la religion d'Isaac Newton," in "Histoire et éthique des sciences et techniques," special issue, *Cahiers d'Épistémé* 1 (2006): 27-39; Tessa Morrison, *Isaac Newton's Temple of Solomon and his Reconstruction of Sacred Architecture* (Basel: Birkhaüser, 2011).

[80] Colin Kidd, *British Identities before Nationalism: Ethnicity and Nationhood in the Atlantic World, 1600-1800* (Cambridge: Cambridge University Press, 2004), 10-23.

evaluations of very different measures of length and time, made by French travelers in the Antilles and south America, or by the agents of trading companies in India and China, were incorporated into a new system of the world.[81] The Newtonians were also much concerned with measuring the densities of a range of substances both at the Mint and in the assay rooms. The *Principia*'s most important claim was that all matter of whatever substance responds to gravity in the same proportion. The only way he could prove this was by testing the movements of balances and pendulums made with "silver, lead, glass, sand, common salt, wood, water and wheat", using gold as the substance against which all other substances were calibrated.[82]

The role of the balance and the pendulum in the rituals of enlightened measurement, set up in Newtonian natural philosophy, was made apparent through these trials on a host of variable goods. Just the same techniques became the most important public rituals of assay offices and the national excise systems of eighteenth century states. As Kula argued, " 'créer une mesure' exige un travail intellectuel complexe. Les différences de qualité d'articles comme le fromage, le beurre, l'huile, la laine et les clous sont si importantes qu'elles font oublier leur seule qualité commune: le poids".[83] In his assays of just such a range of goods, Newton did much more than execute "un travail intellectual complexe". He used the rituals of assaying to show that weight could indeed be considered "une qualité commune". The establishment of this kind of social order, which could conceivably produce reliable and transportable techniques and results, required a regulated network of commodity exchange, and, in turn, helped secure it.

For example, the tobacco leaf whose commodity status depended on tight government regulation of barrel size, imposed and resisted in Virginia plantations and the London and Glasgow docks, ultimately became a reliable commodity through the stringent rituals of the excise laboratories. As in Britain, the leaf also became part of the purchasing system of the French Farmers General, who monopolised its import from Virginia via Glasgow. It was thus the stock-in-trade of eighteenth century fiscal experts such as Antoine Lavoisier, who inspected tobacco outlets, controlled the

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[81] Schaffer, *La fabrique des sciences*, 49-55.

[82] Isaac Newton, *The* Principia: *Mathematical Principles of Natural Philosophy*, trans. I. Bernard Cohen and Anne Whitman (Berkeley: University of California Press, 1999), 807.

[83] Kula, *Les mesures et les hommes*, 55.

excise on goods entering the capital, monitored inflows and outflows of goods through his excise wall round Paris, and helped plan a national munitions industry. For Lavoisier and his collaborators, as Bernadette Bensaude-Vincent has shown, "la balance définit un nouvel espace au coeur du laboratoire, presque un sanctuaire".[84] The term is apt: On the one hand, the figure of the balance embodied in a single set of practical performances an entire range of social meanings in accountancy and commerce, politics and morals: "les gestes de pesée effectués par Lavoisier entrent en resonance avec d'autres pratiques de bialns, d'inventaires, d'algébrisation en usage dans d'autres varieetees culturelles qui sont implicement mobilisées chaque fois que Lavoisier fait appel au jugement de la balance".[85] And these "gestes de pesée" were systematically and ingeniously incorporated within rituals of political performance. Between 1783 and 1785, the French king, his ministers, academicians and administrators became privileged witnesses of Lavoisier's synthesis and analysis of water. In a manner redolent of much older state ceremonial, the chemists sought to persuade their elite public of the fact of water's gaseous composition. Historians agree these rituals were *qualitatively* persuasive. But they also agree that backstage, Lavoisier improvised with the material of his calculations until they seemed convincing. [86] Not the least of the many resources that ceremonies of measurement provided was just this capacity to work behind the scenes until calculus and theatre matched.

As Kula's arguments suggest, such rituals mattered most in commerce and agronomy. The conflicts between rival accounts of the moral economy hinged on the values invested in calibrating price, quantity and production. The agricultural market was supposed to be governed by a moral code, sanctioned by custom and Scripture. Agricultural labour transferred the divine product of God's earth from soil to table. The ultimate producer was God's action in earth. Divinity acted as fertility. Whoever intervened in this process by trading in the sacred territory between the fields and the home, was guilty of blasphemy. In 1759, according to Kula, the procureur du Roi at

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[84] Bernadette Bensaude-Vincent, *Lavoisier. Mémoires d'une révolution* (Paris: Flammarion, 1985), 85-86. My emphasis.

[85] Ibid., 201 and 215.

[86] Frederic Lawrence Holmes, *Lavoisier and the Chemistry of Life: An Exploration of Scientific Creativity* (Madison: University of Wisconsin Press, 1985), 214, 218, and 234.

Nantes announced that since "les différentes denrées qui se vendent à mesure comble" were sold in varying quantities because of heaping of the substance within the standard, "il est donc intéressant pour le public et principalement pour cette partie affligée que la nécessité constraint de vivre de menus grains de fixer et rapporter les dimensions que doit avoir le boisseau nantois".[87] Yet protests exploded whenever and wherever local and idiosyncratic rituals of corn measurement seemed violated.

Customary measures, embodied as example in metal or wooden containers for grain, were treated as sacred objects, supervised by authority, venerated by civic ceremony and stored in treasured sites. In 1732, for example, the British government attempted to impose a standardized measure on the rituals for calibrating the weight of corn. A citizen's jury in the city of Gloucester therefore ritually packed the legally validated container tightly with grain, then slowly poured its contents into the traditional measure, giving a bulkier but lighter and thus acceptable quantity of corn.[88] Consider, as an apt comparison, those seventeenth and eighteenth century Guinea markets where the Akan used weights that varied according to the social status of their commercial partners. Sometimes tools were introduced as means of regulation. In 1753, for example, the Swedish government commissioned an ingenious machine from the expert instrument maker Daniel Ekström that mechanized the process of pouring grain into a measured container, thus allegedly obviating the need for careful manual management.[89] In a host of such cases, measurement rituals were contested, or customized, or treated as sacred.

The invention of metrology

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[87] Kula, *Les mesures et les hommes*, 60.

[88] Richard Sheldon *et al.*, "Popular Protest and the Persistence of Customary Corn Measures: Resistance to the Winchester Bushel in the English West," in *Markets, Market Culture and Popular Protest in Eighteenth-Century Britain and Ireland*, ed. Adrian Randall and Andrew Charlesworth (Liverpool: Liverpool University Press, 1996), 25-45, here p. 34.

[89] Arne Hessenbruch, "The Spread of Precision Measurement in Scandinavia 1660-1800," in K. Gavroglu, ed., "The Sciences in the European Periphery during the Enlightenment," special issue, *Archimedes* 2 (1999): 179-224, here pp. 208-09.

The late eighteenth century then invented a new term for the science of measurement rituals and their world distribution: *metrology*. The term had previously been used, and only rarely, as a technical concept in mathematics. The naval engineer Alexandre Savérien defined it thus in his 1753 *Dictionnaire universel de mathématique et de physique*: metrology was then merely "la géométrie élementaire".[90] Matters changed in 1780 with the work of Lavoisier's contemporary, the Paris mathematics teacher Alexis-Jean-Pierre Paucton. Paucton's *Métrologie* traced measurement's ritual history from its central role in agronomy. He traced measurement rituals through sacred and human history. The convergence of social conflict with antiquarianism was very marked in Paucton's extraordinary book, which eventually gained him the mathematics chair at Strasbourg. Paucton started with contemporary agronomy and the 'guerre des farines' of 1775, conducting experiments on the capacity of current grain measures.[91] Yet, as in Newton's case, he swiftly moved to a long meditation on the virtues of the ancients. They had navigated the oceans and discovered America, as tales of a lost Atlantis proved.[92] They'd constructed vast metrological monuments. The Great Pyramid, to which Paucton also devoted a separate treatise in 1781, was the supreme embodiment of fundamental standards. "La pyramide est un monument qui mérite d'être examiné de nouveau; il n'y en a point de plus capable de répandre un grand jour sur l'antiquité".[93] And these standards, ritualized by antiquity and memorialized in its monuments in just the way Newton also imagined, depended on an unrivalled mastery of the Earth's dimensions. Pauction thus recommended political and economic strategies akin to those of the physiocrats: abandonment of colonial trade, which was a source of luxury and corruption, and its displacement by "les richesses qui seules peuvent rendre une peuple florissante, et augmenter sa population, les fruits que la terre natale produit".[94]

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[90] Alexandre Savérien, *Dictionnaire universel de mathématique et de physique*, 2 vols. (Paris: Rollin/Jombert, 1753), 2: 146.

[91] Alexis Paucton, *Métrologie ou Traité des mesures, poids et monnoies des anciens peuples et des modernes* (Paris: Desaint, 1780), 568-602. See also Kula, *Les mesures et les hommes*, 98.

[92] Paucton, *Métrologie*, 210.

[93] Ibid., 116.

[94] Ibid., 630; Arthur Young, *Voyages en France pendant les années 1787, 1788, 1789*, trad. par H. J. Lesage (Paris: Guillaumin, 1860), 39-40.

It would be very easy but basically erroneous to read Paucton's work as a clear symptom of modern rationality, and to deal with its introduction of metrological vocabulry as nothing but a sign of the coming of the quantifying spirit in the pre-revolutionary conjuncture. In fact, as the vast and politically oriented scope of his project reveals, it was instead typical of Paucton and his contemporaries to construct very strong connexions between measurement techniques, administrative crises and conjectural histories of measurement as a world principle. It is certainly true that metrology's methods would eventually become indispensable to social historians. Bloch prophesied that "un temps viendra, il faut l'espérer, où aucune analyse de la vie régionale, qu'elle soit l'œuvre d'un historien, au sens usuel du mot, ou d'un géographe, ne se concevra sans des cartes de mesures ».[95] But even more rapidly, it became a weapon for a range of political and economic interests. In the 1770s Paucton helped himself to older traditions of orientalist scholarship, especially reports of travelers in the Levant and south Asia who'd gathered comparative information on the variation of measurement practices across markets and courts. There were very close comparisons to be made, therefore, between Newtonian measurement rituals and Paucton's metrology. British merchants and colonial administrators exploited the relationship as key aspects of the enterprises of newly reorganized global trading systems. Between 1777 and 1783, for example, an East India Company revenue collector and printer in Calcutta, Francis Gladwin, organized the translation of substantial extracts from Abu'l-Fazl's *A'in-i-Akbari*, so that what was taken to be a guidebook to Mughal measures, with its details on the management of the Mint, the origin of precious metals, and the ceremonial weighing of the monarch, could be made accessible to the British regime. As Kapil Raj has argued, this was neither the first nor the last administrative attempt to extract useful fiscal information from Abu'l-Fazl's treatise.[96] The declared aim of Gladwin's project was partly to allow this regime to claim it had adopted and displaced former ceremonials and practices of measurement and law. In complete reliance on local experts in Persian and Mughal

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[95] Marc Bloch, "Le témoignage des mesures agraires," *Annales d'histoire économique et sociale* 6 (1934): 280-82, here p. 282.

[96] Kapil Raj, "Mapping Knowledge Go-Betweens in Calcutta, 1770-1820," in *The Brokered World: Go-Betweens and Global Intelligence 1770-1820*, ed. Simon Schaffer *et. al.* (Sagamore Beach: Science History Publications, 2009), 105-150, here p. 130.

administrative traditions, British scholars published voluminously on Indian systems of weights and measures.

The East India Company used these principles to establish a 'permanent settlement' of farm and property rights. This violent reorganisation of measures was decisive in the reorganisation of Bengal agronomy in 1793. The Company reckoned it necessary there should be 'a patient and laborious scrutiny of individual rights, together with a minute and detailed survey of the extent, cultivation and productive powers of the territory'.[97] After 1795 the financier and administrator Henry Colebrooke produced a major analysis of Indian weights and measures, linking this with his accounts of indigenous astronomy, celestial mechanics and cosmology.[98] And from 1800 the Moravian missionary and botanist Benjamin Heyne worked in the newly conquered territories of Mysore as plant collector and surveyor. In 1814 he published his remarkable statistical account of Indian measurement practices. Heyne's records, often produced in close collaboration with Brahmin informants who could apparently recount by heart Tellugu versions of Sanskrit works on land mensuration. They detailed the relation between body techniques, traditional measures and the demands of economic and social administration. Heyne stressed the great accuracy of the wide range of current measures, explained the rituals that defined units of weight, length or area, and argued that though "the introduction of English measures would be commodious for Europeans, on account of the ignorance of the lower classes of Indians it would expose them to great impositions".[99] In relations sustained with the indigenous experts on whose measurement practices the Europeans relied, it is certainly not true that measurement belonged to one side of such processes, tradition to the other.

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[97] Sarvepalli Gopal, *The Permanent Settlement in Bengal and its Results* (London: Allen and Unwin, 1949), 24. See also Ranajit Guha, *A Rule of Property for Bengal: An Essay on the Idea of Permanent Settlement* (Paris: Mouton, 1963), 13.

[98] Rosane Rocher and Ludo Rocher, *The Making of Western Indology: Henry Thomas Colebrooke and the East India Company* (Abingdon: Routledge, 2012), 24-32.

[99] Benjamin Heyne, *Tracts, Historical and Statistical, on India* (London: Robert Baldwin, 1814), 172-80. See Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Scientific Knowledge in South Asia and Europe, Seventeenth to Nineteenth Century* (Delhi: Permanent Black, 2006), 69.

It was thus no coincidence that the word *metrology*, as the name for the science of measurement rituals, at last entered the English language too. It did so first through the East India Company's principal Mint administrator James Prinsep and the mathematics teacher Patrick Kelly. Following Heyne's statistical accounts, Prinsep conducted a census of as many different measurement systems at work in the subcontinent as he could collect, and commissioned models of each set of standards and recipes for their ritual administration. Kelly aimed to produce universally valid reckoners for coinage values and standards translations through the global commercial system. Prinsep then sent these models from Calcutta to London in a calibration programme completed in 1823 and published in 1832 with a title both eloquent and, for the British, unprecedented: *Oriental metrology*.[100]

Metrology entered the British world through India. Debates then raged about the relation between the ritual basis of such measures and the challenges of uniformity. Prinsep urged that standardization could "only be done in the gradual process of time by the growing intercommunion of the multitudes engaged in the internal traffic of the country".[101] His opponent in the fights around *Oriental metrology* was a Bombay military surveyor and fierce evangelical, Thomas Jervis, who instead backed centralized imposition of measurement standards throughout British India. It would be easy but deluded to see Prinsep as the conservative, Jervis as the rationalizer. The opposite, if anything, is the case. Using arguments like those of Newton, Jervis found the basis for all length measurements in ancient sources, especially the Bible. A universally distributed ancient set of measurement ceremonies had been developed in the Levant by divine inspiration and thence diffused worldwide. "The universality and simplicity of the scriptural scheme of metrology", so Jervis argued, would allow the effortless legal imposition of this system throughout the empire.[102] "The poor

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[100] Patrick Kelly, *Oriental Metrology; Comprising the Monies, Weights and Measures of the East Indies and Other Trading Places in Asia, Reduced to the English Standard by Verified Operations* (London: Longman, 1832), 11; James Prinsep, *Useful Tables, Part the First: Coins, Weights and Measures of British India* (Calcutta: Baptist Mission Press, 1834), 75-77.

[101] Prinsep, *Useful Tables*, 76.

[102] Thomas B. Jervis, *Records of Ancient Science Exemplified and Authenticated in the Primitive Universal Standard of Weights and Measures* (Calcutta: Baptist Mission Press, 1835), 86

unlettered *ryot* or cultivator, the needy and despised heathen", would, so he predicted, easily see how a moralised system of metrology would protect him against exploitation and embed him in the imperial system of values.[103] From then on, imperial metrology and the significance of sacred rituals and monuments, whether in Europe, India or Egypt, seemed evident, especially to the colonial powers.

This is the end of a journey from the northern Pacific coasts via the royal ceremonials of European and Mughal rule and the politico-economic interests of antiquarians and enlightenment experimenters to the concerns of Indian administration at a moment of world economic and political crisis, illuminated by a Telugu version of a Sanskrit text on measurement, or by the interpretation of Jewish metrology by an evangelical engineer. In his article *Hearing voices*, Sanjay Subrahmanyam rightly insists that 'modernity is historically a global and conjunctural phenomenon, not a virus that spreads from one place to another'.[104] The aim here has been similar, to restore a certain kind of symmetry to the long-term workings of measurement and to escape the sense of a monotonic advance of precision as part of an inevitably modern order. Rather, by placing measurement ceremonies within a more heterogeneous global historical geography, it also becomes possible to see how Bloch's analyses of ritual practices and conceptions of the universe can be given their just place in a story of the modern sciences. These histories show that supposedly silent traders in fact spoke in many different voices.

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[103] Ibid., xiii; see Matthew H. Edney, *Mapping an Empire: The Geographical Construction of British India, 1765-1843* (Chicago: University of Chicago Press, 1997), 268-87.

[104] Sanjay Subrahmanyam, "Hearing Voices: Vignettes of Early Modernity in South Asia, 1400-1750," *Daedalus* 127, no. 3 (1998): 75-104, here p. 99-100.